Article

Australian Dust: From Uplift to Uptake

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Simply put the Southern Ocean is anaemic! That is to say that primary production is often limited by the availability of iron. As phytoplankton grow they take up carbon from surface waters allowing more CO_2 from the atmosphere to dissolve and thus lowering its concentration in the atmosphere. Aeolian dust delivers iron to oceans and in the late 1980's John Martin's *iron hypothesis* mused about how more dusty conditions during the last glacial maximum might have increased the *drawdown* of CO_2 from the atmosphere by phytoplankton. He famously joked that *give me a tanker of iron and I'll give you an ice age*.[1] The NZ-led Southern Ocean Iron Enrichment Experiment (SOIREE) tried just that. The results (nicely summarised at the RSNZ website *www.rsnz.org*), that conclusively show the dramatic effect of iron additions, also raised some questions about the *real world* delivery of iron, as opposed to simply mixing an iron solution into the prop wash of a ship.

More than 80% of global dust deposition to the oceans is to those in the Northern Hemisphere from large sources like the Sahara and Gobi deserts. But the impact of dust on biota in a particular region is not necessarily a function of mass flux. Quite the contrary - the scarcity of dust in the Southern Hemisphere means that dust processes there are of especial importance but observational data is sparse. The cartoon (Fig. 1) shows the overall process from uplift of Australian soil and production of dust to uptake of iron by phytoplankton.

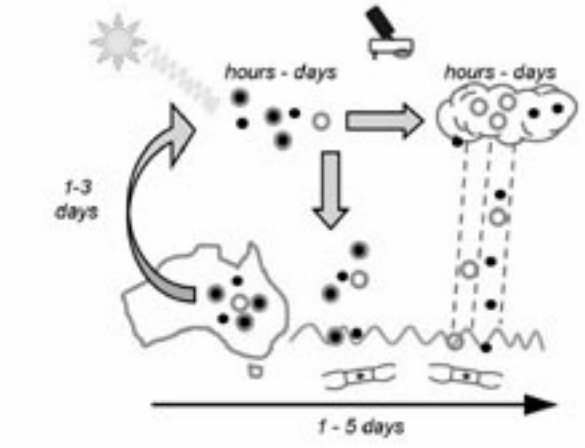

Fig. 1. Schematic sequence of events from uplift of Australian dust to uptake of iron by biota.

In general iron is taken up from seawater by phytoplankton from the dissolved phase via a ligand-mediated process. Therefore, factors that influence the dissolution of iron from dust also govern the uptake of iron by phytoplankton. During uplift and transport by dust storms, abrasion of soil produces fine particles. Abrasion processes can also redistribute more soluble forms of iron onto smaller grains.[2] Other dust interactions during transport with light[3] and cloud water[4] also influence the dissolution of iron from dust.

Some models for the dissolution of iron from dust, based on Northern Hemisphere data,[5] explicitly include the solubility enhancing effect of pollutants like SO_X and NO_X. But an important consideration for the Australian case is that the atmosphere of the Southern Hemisphere is pristine in comparison. For this reason, our laboratory-based solubility experiments are carried out in pure water acidified with sulfuric acid and use both soils collected from dust source regions and dust collected during dust storms. The Southern Hemisphere case may be a good model for the influence of the atmosphere on the iron cycle during the dustier, last glacial maximum and will, in any event, inform predictions of iron supply as Australian dust emissions increase due to human-induced land-surface degradation.

The major dust storm of 23 October 2002 (Fig. 2) was the largest event in more than 40 years and it entrained dust from large areas of Eastern Australia. The storm front was some 2400 km long, 400 km wide, and 1.5-2 km high and the image also shows smoke plumes from large bushfires. The total suspended load was estimated at 3.4-4.9 million tonnes.[6] After the event passed off the Queensland coast, satellite pictures and wind back trajectories showed that the plume bifurcated, with dust being deposited into both the high-nitrate, low-chlorophyll (HNLC) low iron waters south of NZ, and into the low-nitrate, low-chlorophyll (LNLC) low iron waters NE of NZ and into the Gulf of Carpentaria to the north of Australia.

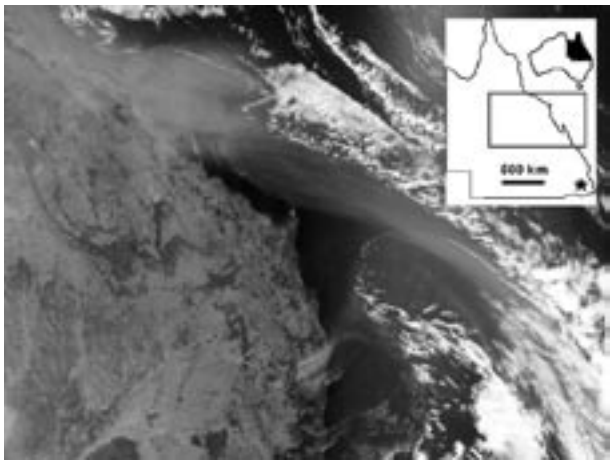

Fig. 2. The 23 October, 2002major dust storm. This SeaWIFS image (courtesy of NASA) shows the storm ca. 2400 km long x 400 km wide x 1.5-2 km high; inset map * = Brisbane.

Dust supply to the southern HNLC region might be expected to stimulate iron-limited diatoms in these waters, and in the northern LNLC region, dust supply might have stimulated nitrogen-fixers such as *Trichodesmium*, which

is known to be Fe and/or Fe + P limited. However, examination of composite satellite ocean color images after the event revealed no significant increase in chlorophyll concentrations across this region. Why not? We believe the answer lies in the way in which iron dissolved from dust.

We began with simple experiments to assess the limits of iron solubility in the atmosphere in the absence of high energy UV radiation and ligands (like oxalate, SO_X and NO_X). The results (Fig. 3) agree with the general trend of Norther Hemisphere studies and show that the iron component of soils and dusts can be partitioned into three classes, namely *readily-released* at <1% total iron, *acid-leachable* at up to 15-30% of total iron, and the remainder *refractory*.

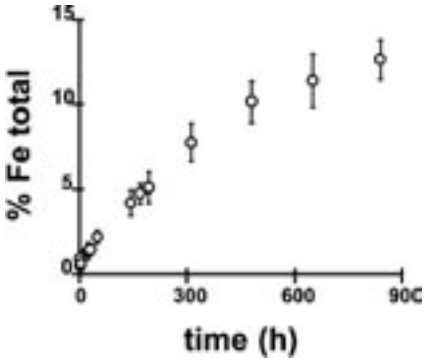

Fig. 3. Dissolution of iron from untreated Thargomindah soil over time at pH 2.1; data from the middle of the Malee dust producing region - 2/3 to the west along the Queensland/NSW border and averaged for grain size fractions 5-11, 11-20, 20-30, 30-44, 44-53, and 63-75 μm.

Readily-released iron is that which is found in the dissolved phase after not much more than the mixing time of our system – just a few minutes, *viz*. the y-intercept of a dissolution plot. Readily-released iron seems comparable with the *instantaneously soluble fraction* of Fe and Al in natural aerosols reported by other workers,[7] and may represent ferrihydrite (frequently and incorrectly described as *amorphous iron oxide*). The acid-leachable portion comes out more slowly, a period that ranges from hours to many days. The portion of this that is bioavailable can be approximated by a tangent to the dissolution curve.

Based on these arguments, we would not expect to see a response by biota in the weeks immediately following a dust delivery event. Rather, such events would serve to top up a supply of slow release iron where iron supply is limited by processes that retain dust, or at least the iron rich coatings from dust grains, in surface waters. This buffering of iron supply may explain the lack of rapid response by biota to dust events. Our current work is following this line of enquiry.

References

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Letter to the Editor

Re: *Back to the Basics* (*This Journal,* **2007***, 71*, 50-53)

I read Peter Schwerdtfeger's article *Back to the Basics* in the last issue of the journal with considerable interest and sympathy. I also reflected on the numerous articles with similar messages that I have read over the last twenty or so years.

As far as Government funded Research, Science and Technology is concerned, why, if it is so obvious, do the powers that be not get the message that investment in R&D is a good thing? The public servants who put the message forward and the politicians who read it are some of the brighter people around. They are used to making long-term decisions around complex subjects. Deciding on an appropriate level of research funding for New Zealand should be straightforward. So is it possible that they have the view that the current amount allocated is about right? In fact, given that the level of Government spending on R&D as a percentage of GDP is drifting down year by year, they may well think that it is too high as it is?

In which case, if we are to persuade the decision makers to allocate more funding to research, basic or applied, then the first step is surely to try and understand where they are coming from? If we can do that, then possibly we can then formulate an argument that will persuade decision brokers and makers that spending more on R&D is a better option than more spending on health, education, welfare, *etc*.

So let me give you a challenge: think like a Treasury official or a Cabinet Minister or a politician with all the multitude of different demands being made on you in allocating the tax-take. Rather than think of reasons why funding should be increased, do the reverse and submit in 100 words or less your reason(s) why research funding should **not** be increased.

I am hoping that collectively we may already know the answer, and if it can be clearly expressed we may then be able to formulate an appropriate *plan of attack* that would see R&D expenditure in New Zealand raised to that found in other OECD countries. If nothing else, I might expect some humorous responses from my more imaginative colleagues.

Yours sincerely
David M. Bibby, FNZIC.

Please send your responses to the Editor: *brian.halton@vuw.ac.nz*